Construction and Building Materials 178 (2018) 19–31

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Fresh-state performance of recycled aggregate concrete: A review

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HIGHLIGHTS

- Literature review on the fresh properties of recycled aggregate concrete (RAC).
- Workability, stability, heat of hydration, air content and density were analysed.
- Control over the recycled aggregates' manufacture is key to obtain high quality RAC.
- Predictable properties are achieved by adding adequate amount of compensating water.

ARTICLE INFO

Article history:
Received 16 January 2018
Received in revised form 8 May 2018
Accepted 17 May 2018

Keywords:
Recycled aggregates
Concrete
Sustainability
Fresh properties
Workability
Stability
Air content
Fresh density

ABSTRACT

This paper presents a literature review concerning the fresh properties of concrete containing recycled aggregates from beneficiated construction and demolition wastes. It starts with the identification of the main variables affecting the workability of concrete, such as the quality and moisture state of the recycled aggregates. The effectiveness of water-reducing admixtures and of mineral additions on the fresh properties of recycled aggregate concrete is also analysed. A brief insight is given on the influence of using recycled aggregates on the main characterizing parameters of the material's rheological behaviour. Other properties of recycled aggregate concrete in its fresh state are also discussed, including stability (i.e., bleeding and segregation), temperature of hydration, air content, and fresh density.

Contents

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https://doi.org/10.1016/j.conbuildmat.2018.05.149
0950-0618/

1. Introduction

One of the approaches most capable of guaranteeing increased sustainability in construction, demolition and renovation operations is to diminish the impacts associated to the materials used. Recycling of construction materials is not the optimum solution in a "greater sustainability" context, as it is preferable to implement specific strategies that can reduce the use of raw materials and prevent the production of waste. This can be achieved by increasing the service life of buildings, which would prevent their early decommissioning and the consumption of new materials and, consequently, the production of construction and demolition waste (CDW). Nevertheless, in current practice, there are several factors that limit the employment of those approaches, thereby making recycling of CDW into usable recycled aggregates (RA) as the next best solution.

In light of the not-so-recent changes in European legislation concerning the management of wastes – Directive 2008/98/EC [1], by 2020 a minimum of 70% by weight of all non-hazardous and non-naturally occurring CDW should be prepared for reuse and recycled. One of the first steps to achieve this is by institutionalizing the practice of selective demolition, wherein it becomes fairly easy to segregate all components and handle each one separately. In accordance with section 17 of the European Waste Catalogue [2], CDW may be divided in several main components including: fragments from crushed concrete leading to the production of recycled concrete aggregates (RCA); crushed masonry walls, the beneficiation of which produces recycled masonry aggregates (RMA); and mixed debris containing the two previous types of materials, which results in the production of mixed recycled aggregates (MRA). All of these are within the scope of the EU's Construction & Demolition Waste Management Protocol [3] and can be used as partial or total natural aggregate (NA) replacement in the production of structural concrete.

However, in spite of the extensive research and positive experience on the use of RA [4–6], there are still several barriers in place to the their greater use in the production of new construction materials, including: lack of confidence of those involved in the construction industry; the inexistence of adequate recovery systems, with high quality control of processing and reselling with affordable prices; lacking standards and specifications that can allow a better understanding of the effects of using such materials on the performance of concrete [7,8].

1.1. Research significance

The importance of processing CDW into RA and using them in new construction materials is undeniable. In light of the recent efforts to further reduce of the environmental footprint of several products within the construction industry, efforts have been focused on concrete due to its considerable contribution to the World's total CO_2 emission. Indeed, a vast number of studies have been published over the last four decades claiming the feasibility of the use of RA as partial NA replacement in the production of concrete. However, in spite of the widely observed positive findings, most of the research has focused on the mechanical and durability-related performances, with less emphasis given to the fresh properties of RAC. Overlooked by most, the behaviour of concrete in the fresh state can give an insight to its performance in the hardened state. The literature clearly shows that much of the research has been carried out without taking into consideration the importance of the moisture state that the RA must be into result in mixes with acceptable levels of workability over the course of time. Moreover, a clear knowledge gap can be easily observed in the concept of the total w/c ratio *versus* effective w/c ratio and how this considerably affects both fresh and hardened properties. Furthermore, several studies have been carried out making comparative assessments on the material level, wherein the mix design of RAC was made by directly replacing NA with RA on the basis of their weight rather than by volume thereby influencing the mixes' aggregate to cement ratio. Therefore, this literature review serves to shed more light on these and other concepts related to the fresh properties of RAC, in order to guide future experimental studies in a more industry-focused perspective and facilitate a greater use of RA in concrete.

1.2. Methodology

The strategy followed in the preparation of this literature review involved first the making of provisional table of contents containing the main properties of concrete in the fresh state. Afterwards, an initial list of publications was selected based on the relevance of the publication's title and contents relative to this paper's theme and table of contents. As each study was individually evaluated, all relevant information regarding the effect of RA on the fresh properties of concrete were gathered and organized in spreadsheets. Thereafter, based on the authors' extensive experience on the production of RAC, the main results that can provide a greater representation of literature's findings and research trends were transcribed in each of their corresponding sections of table of contents.

2. Workability

Workability of concrete can be summed up as the amount of internal work required to reach the maximum compaction of the material [9]. To characterize the behaviour of this internal work and appearance of the fresh mix, qualitative (e.g., harshness, cohesiveness, stiffness, compactability), quantitative empirical (e.g., slump) or quantitative fundamental (e.g., viscosity, fluidity, yield value) methods are used [10]. Quantitative empirical methods provide a single measurement and thus are referred to as one-parameter or single-point tests. The slump and slump flow test methods, which belong to this category, were the most widely used methods to characterize the workability of RAC and are the basis of the assessment in the following sections, unless expressed otherwise. The most adequate approach to effectively quantify and evaluate the workability of concrete is with the application of two-parameter or two-point tests, which deliver fundamental properties to study rheology of concrete (i.e., yield stress and plastic viscosity) [10].

A greater emphasis is given to this section concerning the several variables affecting the workability of RAC. This is because more information was found on the subject and some of its characterizing properties (i.e., slump and slump flow) are essential when specifying the concrete's requirements in a ready-mix concrete plant. Since the factors discussed in this section have a similar effect, to a certain extent, in other fresh properties, it was